Informing research and education: Common bottlenose dolphin (*Tursiops truncates)* abundance analyzed across environmental variables near St. Catherine's Island, GA from 2010-2020

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Introduction

The coastal ecosystems of the southeastern United States (SE US) are home to a diverse range of marine life, with the common bottlenose dolphin (*Tursiops truncatus,* hereby referred to as dolphins) being one of the most prominent species. These dolphins, whose populations are protected under the Marine Mammal Protection Act, can be both resident populations (remain in specific areas year-round) and migratory groups (move along the coast from offshore habitats) (16 U.S.C. 1361-1407). Resident groups occupy estuarine and inshore habitats year-round and are more directly affected by localized environmental conditions and human activity, while pelagic populations typically stay offshore, following broader prey distributions (Rosel et al., 2009; Wells et al., 2009). These ecological differences are highlighted within their feeding behaviors. For example, resident dolphins use tidal cycles to develop specialized foraging strategies. During low tide, they often use "mudding," a technique that involves trapping fish in sediment plumes, and, during high tide, they sometimes wait near creek and river mouths to capture prey flushed out of marshes (Barros & Odell, 1990; Lewis & Cox, 2016). In contrast, pelagic dolphins target schooling fish and squid in offshore waters, where prey distributions are more variable and less tied to tidal cycles. Together, these dolphins provide vital ecosystem services for coastal habitats by regulating prey populations and maintaining the balance of marine food webs (NOAA Fisheries, 2021). They feed on a variety of estuarine and nearshore fish and squid species, and, through this predation, help regulate prey populations and contribute to community structure and stability (Barros & Odell, 1990; Gannon & Waples, 2004). However, dolphins are increasingly vulnerable to the impacts of climate change and anthropogenic factors (Lane et al., 2015), such as habitat degradation (Weaver, 2021), pollution from terrestrial sources (Barratclough, 2019), and commercial and recreational fishing (Powell & Wells, 2010). These pressures negatively affect their habitats, food sources, and migration patterns, making it crucial to recognize the factors affecting their populations. Therefore, it is important to understand dolphin population structures across 1) space 2) time and 3) environmental factors to determine changes in dolphin populations structures from climate and anthropogenic factors and inform conservation and management efforts.

Studies from the SE US established an understanding of dolphin population structure, distribution, and site fidelity across spatial-temporal factors. For instance, common bottlenose dolphins in this region often show strong site fidelity, with individuals returning to the same estuarine habitats over time, displaying a preference for specific coastal ecosystems (Speakman et al., 2006). These patterns are representative of inshore resident dolphins, which contrast with pelagic or offshore populations that range more widely and exhibit less localized habitat use (Rosel et al., 2009; Wells et al., 2009). In addition to site fidelity, seasonal differences in dolphin abundance have been widely documented, though these differ across regions. In some areas, dolphin presence increases during colder months, likely due to changes in prey distribution or water temperature (Torres et al., 2005). In other locations, higher abundance has been observed during warmer seasons or transitional periods like fall, emphasizing the influence of local ecological conditions and resource availability (Balmer et al., 2008). These regional differences stress the need for region-specific studies, as patterns are not consistent across estuarine systems. While photo-identification and mark-recapture methods have also provided useful estimates of abundance and movement (Read et al., 2006; Rosel et al., 2011), knowledge gaps remain in regard to baseline population dynamics. Collectively, these studies emphasize the importance of regional assessments of dolphin populations over longer periods of time, as spatial distribution and site fidelity vary significantly across coastal habitats with dynamic environmental conditions and anthropogenic impact. This regional and long-term population data is critical for future conservation and management efforts of dolphins in the SE US.

The Georgia coast, located in the center of the South Atlantic Bight, experiences extreme tidal ranges of approximately 6-8 feet. These tidal systems continuously shape and reshape the barrier islands, salt marshes, tidal creeks, mud flats, and brackish river habitats that make it a unique ecosystem (Bishop, 2011). Dolphins are common residents in coastal Georgia habitats and typically belong to one of three stocks (a group of animals that occupy the same area and interbreed (NOAA)): the South Georgia Estuarine Stock, the Central Georgia Estuarine Stock, and the Northern Georgia/Southern South Carolina Estuarine Stock (NMFS, 2023). The region around St. Catherine's Island falls within the Central Georgia Estuarine Stock, though stock boundaries remain somewhat unknown due to limited long-term data (Taylor et al., 2016).

Compared to neighboring states like South Carolina and Florida, Georgia is relatively understudied in dolphin research. Much of what we know about estuarine dolphin populations in the region comes from scarce photo-identification efforts by the Georgia Department of Natural Resources, supported by NOAA funding. These studies have focused around Brunswick, Georgia, which is near one of the Southeast's most concerning pollution sites, the LCP Chemicals Superfund Site in the Turtle River estuary. Decades of industrial dumping has led to high concentrations of toxic compounds, including polychlorinated biphenyls (PCBs) and pentachlorophenol (PCP), both of which are known to have serious effects on marine mammals (Balmer et al., 2008; NOAA DARRP, 2025). In a 2011 health assessment, researchers found that dolphins in this area had some of the highest PCB concentrations recorded in wild populations, and genetic studies determined that these pollutants have decreased reproduction, with dolphin populations reduced to around half their expected size (Barratclough, 2019). Additionally, dolphins from Sapelo Sound overlap with individuals observed around St. Catherine's Island, suggesting that even dolphins outside known hot spots can be affected by this pollution and ecosystem stressors.

Therefore, this research will address a need for more comprehensive studies that integrate multiple environmental variables over extended periods of time. Specifically, we will investigate the combined influence of tidal states, season, and temperature on dolphin abundance around St. Catherine's Island. This study will focus on three main questions <u>targeted at two different audiences</u>:

- **RQ1**: How do variations in daily tide states, season, and monthly average temperatures from 2010-2020 influence the abundance and distribution of common bottlenose dolphins around St. Catherine's Island?
- **RQ2a**: What patterns can be observed in the sightings of the individual dolphin, Thelma, in relation to these variables?
- **RQ2b**: How can we best communicate our findings to the general public through education and outreach materials?

Addressing RQ1 and RQ2a are important for developing a better understanding of how environmental changes impact bottlenose dolphins along with informing effective conservation strategies in these vulnerable coastal systems. Furthermore, by highlighting the impact of environmental changes on charismatic megafauna like dolphins, RQ2b will also engage and inform the general public, developing greater awareness and support for marine conservation.

Methods

Study Site

This study was conducted in the immediate waters surrounding St. Catherine's Island, a barrier island located off the coast of Georgia (Figure 1). The St. Catherine's study site was bound by Ossabaw Sound at the Ogeechee River (31.8526° N) to the north, Sapelo Sound at the northern tip of Sapelo Island (31.5373° W) to the south, North Newport River (-81.2589° W) to the west, and St. Catherine's Sound (-81.1427° W) to the east. St. Catherine's Island is made up of three primary geologic features: island cores, beach ridge complexes, and salt marshes. These formations create a diverse and dynamic landscape, supporting wide variety of habitats, from layered mud and silt to structureless muddy peat. The island's muddy facies, which can preserve shells when shell material buffers the acidic conditions, reflect its complex geologic history (Bishop, 2008).

St. Catherine's Island is one of Georgia's most underdeveloped barrier islands, known for its significant ecological, geological, and cultural history. The island is a private nature preserve and research site where coastal ecosystems, stratigraphy, and 6,000 years of human history are studied (National Park Service, 2023). The island's rich fossil record and mixed range of marine invertebrates, especially crustaceans, polychaetes, and mollusks, highlight its importance for marine biodiversity. Crustaceans make up approximately 40% of all species found, with amphipods and decapods as major contributors, alongside polychaetes and mollusks (Prezant et al., 2009).

The surrounding waters of this unique barrier island, with its complex estuarine environment and critical habitats, such as tidal creeks and marshes, are ideal for studying common bottlenose dolphins. These dolphins rely on the rich and productive habitats of the area, where tidal movements, nutrient cycling, and diverse marine life support both resident and migratory dolphin populations. St. Catherine's Island is especially well-suited for researching dolphins due to its preserved natural environment and minimal human activity, allowing for observations in an ecosystem that remains largely undisturbed. Despite its ecological richness and low levels of anthropogenic influence, the region remains understudied, presenting a valuable opportunity to explore how environmental factors like tides, season, and temperature influence dolphin distribution and behavior.

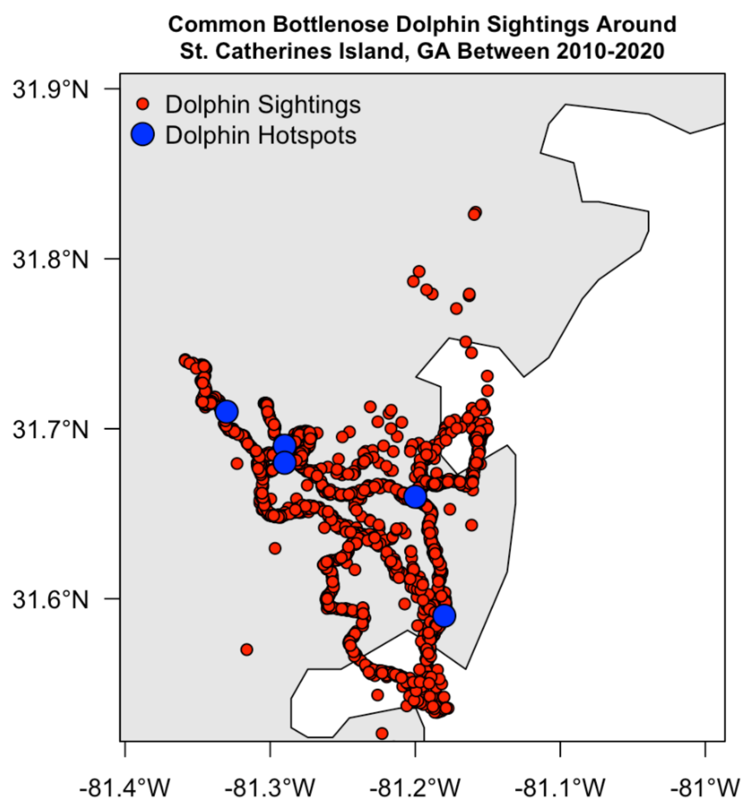

Figure 1: *Map of total common bottlenose dolphin sightings around St. Catherine's Island, Georgia between 2010-2020.* Red points show total individual dolphin sightings recorded during boat surveys. Blue points indicate the top five dolphin sighting hotspots, including Walburg Creek, South Newport River, North Newport River, Barbour River, and Sapelo Sound. Coastal features and tidal creeks are shown in gray.

Data Collection

Biweekly dolphin surveys were conducted over an eight-year period, from April 2010 to February 2020, to capture seasonal and temporal variations in dolphin sightings and environmental conditions. Dolphin surveys were conducted using a standardized boat-based methodology. The survey vessel traveled at a "survey speed" of approximately 10 mph to maximize dolphin sighting efficiency while minimizing disturbance. During each survey, we actively scanned the water for dolphin activity. Upon sighting one or more dolphins, the vessel approached at a slow speed to avoid causing stress or altering their natural behavior. Once within proximity, the following data was collected for each dolphin sighting: 1) date and time, 2) latitude and longitude coordinates, 3) current tide state, 4) surface water temperature, 5) total number of dolphins, 6) specific waypoints added to the GPS, and 7) high-resolution photographs of dorsal fins for individual identification and later analysis. Once the survey was complete, photos were reviewed and cataloged in the NOAA FinBase database, which is used by researchers across the U.S. to track individual dolphins. Accessing this long-term data set allowed us to study dolphin localized movements, social associations, and residency patterns at the St. Catherine's study site.

Environmental variables

For each environmental variable, we assessed effort-corrected dolphin sighting rates (sightings per survey per kilometer of transect) to account for variation in survey effort and the number of surveys conducted across different years and seasons (RQ1 and RQ2a). This standardization confirms comparability between surveys of different lengths or durations.

Tides

Tide data was gathered in the field during each dolphin survey using NOAA's Tides and Currents database as a reference. We examined how both high and low tides impacted dolphin presence, as different tidal stages can affect prey availability and dolphin foraging patterns. However, we did not collect incoming and outgoing tides for each sighting.

Season

Each dolphin sighting was categorized by season based on the month that it was recorded. Seasons were defined as: winter (December-February), spring (March-May), summer (June-August), and fall (September-November). These seasons helped us understand how dolphin abundance changed throughout the year, specifically in relation to temperature.

Temperature

Water temperatures were obtained for each dolphin sighting using a temperature probe mounted to the vessel and accessed using the onboard Garmin ECHOMAP UHD 70 chartplotter/sounder. Continuous depth and temperature readings were taken using the single-beam sonar transducer to provide accurate and location-specific temperature data. Temperature data was analyzed to determine its influence on dolphin abundance and behavior within the study area. These findings can provide knowledge on the effects of climate change on dolphin distribution and abundance.

<u>Case Study for the General Public</u>

To further our understanding of how environmental factors affect dolphin abundance and distribution, a focused case study on an individual dolphin was conducted. Thelma, a well-documented common bottlenose dolphin frequently sighted within the study area, was selected for this analysis based on her consistent presence in the region and the distinctive features of her dorsal fin (Figure 2). This case study looked at how specific environmental variables are associated with Thelma's sightings to provide insights into how individual dolphins might respond to environmental variability. In addition to its scientific role, this case study supports ongoing outreach efforts in collaboration with Billigan Tours and Captain Bill Whiteman, a local ecotourism company around St. Catherine's Island that offers dolphin tours to the general public. As part of this outreach, two educational products were created. The first was a brochure designed in Canva to provide ecotour participants with accessible information about common bottlenose dolphins, including identification techniques, behavior, and conservation efforts. The second was an interactive ArcGIS Story Map focused specifically on Thelma's history, movement patterns, and sightings within the study area. These products build on existing information about Thelma, and other common bottlenose dolphins, provided by the Georgia Dolphin Ecology Program.

Figure 2: *Dorsal Fin of Thelma.* Photo taken under NOAA permit #21134. Georgia Dolphin Ecology Program. Dolphin, Thelma, who was first spotted in 2008, has a unique mark that is distinct and recognizable. She is often spotted along the North Newport River west of Halfmoon Marina and around Johnson's Creek.

Results

Total Dolphin Sightings (RQ1)

Dolphin abundance was first compared across tidal states to determine whether tide influenced abundance (Figure 3). We found that slightly more sightings occurred during high tide (54.5%) than low tide (45.5%).

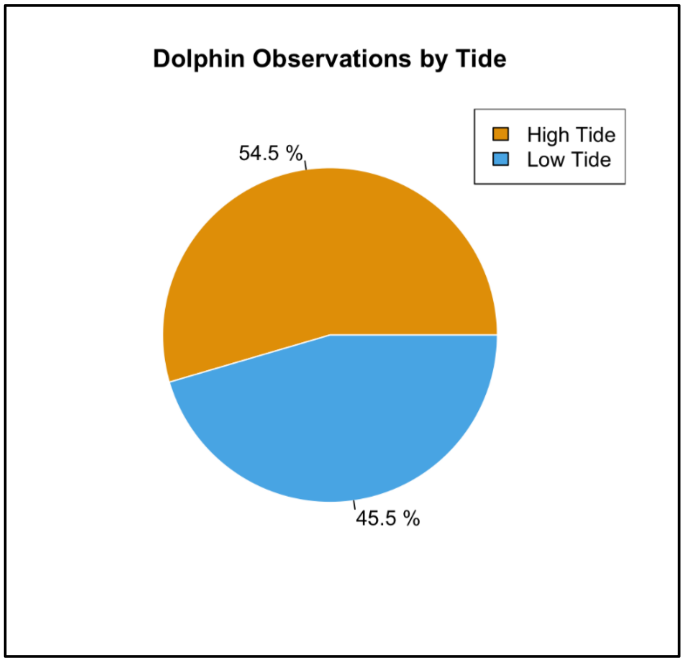

Figure 3: *Dolphin abundance by tide.* A pie chart shows a slightly greater percentage of sightings per survey occurred during high tide (54.5%; orange) than low tide (45.5%: blue).

Seasonal patterns revealed stronger differences (Figure 4). Dolphin abundance was highest during summer (36.8%) and spring (33.5%) compared to winter (17.4%) and fall (12.3%) (Figure 4), highlighting that dolphin abundance was not evenly distributed across the year.

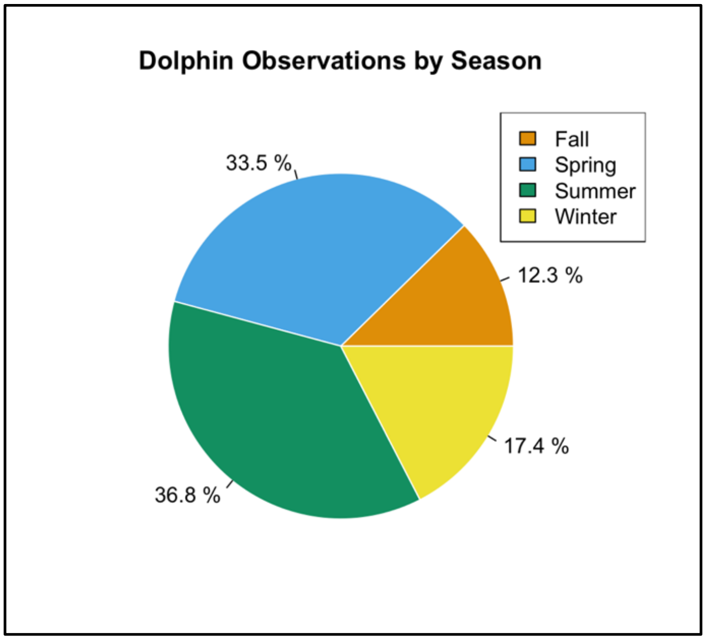

Figure 4: *Dolphin abundance by season.* Sightings per survey were most frequent in summer (36.8%; green) and spring (33.5%; blue), with lower proportions in winter (17.4%; yellow) and fall (12.3%; orange).

To further explore seasonal trends over time, we examined trends in dolphin abundance across seasons from 2010 to 2020 (Figure 5). Spring and summer showed higher numbers of dolphin sightings per survey compared to fall and winter. There was a noticeable curved pattern throughout the decade, with dolphin abundance increasing in the earlier years, peaking between 2015 and 2017, and then slightly declining in more recent years.

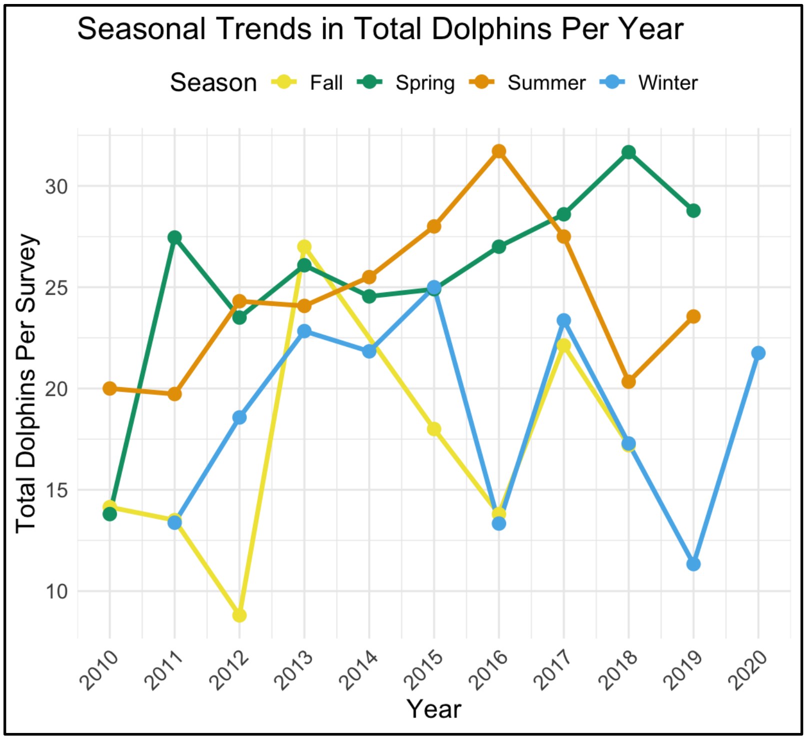

Figure 5: *Seasonal trends in dolphin abundance from 2010 to 2020.* Spring (green) and summer (orange) showed higher dolphin abundance than fall (yellow) and winter (blue).

These findings were explained in more detail through a boxplot of dolphin abundance by season (Figure 6). Sightings were higher during spring and summer surveys, with spring showing the most consistently high values across years. In contrast, fall and winter had lower median dolphin sightings per survey and greater variability between surveys.

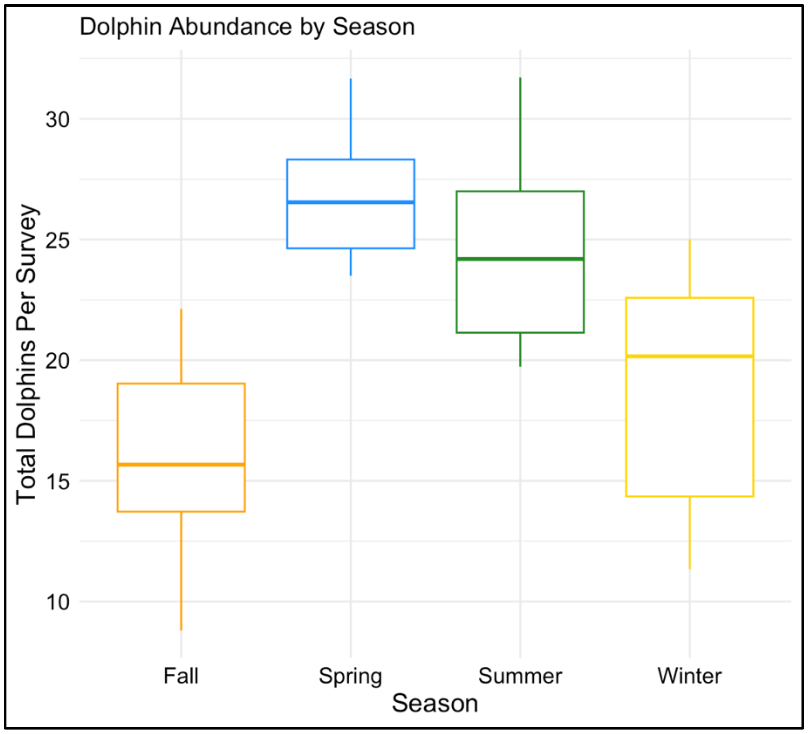

Figure 6: *A boxplot of dolphin abundance by season*. This figure showed spring (blue) and summer (green) had higher dolphin counts, while fall (orange) and winter (yellow) showed lower median values and greater variability. Boxes represented the interquartile range, and whiskers extended to the minimum and maximum values within 1.5 times the IQR.

Temperature also appeared as an important environmental variable. Warmer temperatures were associated with more dolphins observed per survey (Figure 7). This relationship suggests that seasonal and environmental conditions, like temperature, could shape when and where dolphins are most likely to be sighted.

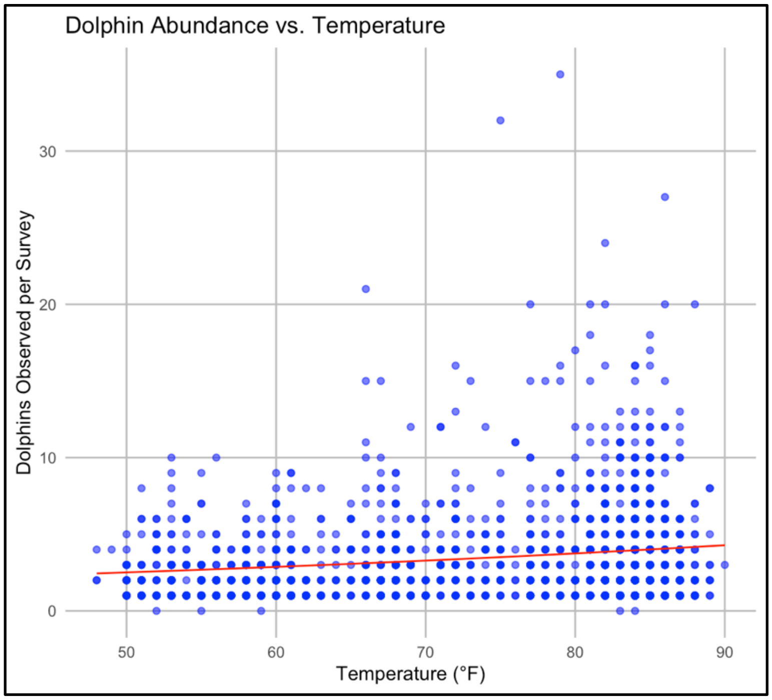

Figure 7: *Relationship between dolphin abundance and temperature (°F).* Each point on this scatterplot represents the total number of dolphins observed during a single survey. Warmer temperatures corresponded to a higher dolphin abundance, as highlighted by the slight upward trend in the fitted red line.

<u>Individual Sightings of Thelma (RQ2a)</u>

We examined whether Thelma followed the same environmental patterns as the broader population. Although she was seen slightly more often during low tide, her abundance did not show strong differences across tide states (Figure 8). Similarly, her seasonal sightings were more evenly distributed compared to the overall population trends (Figure 9). While she was more observed in summer (34.1%) and winter (24.4%), the differences across seasons were not pronounced.

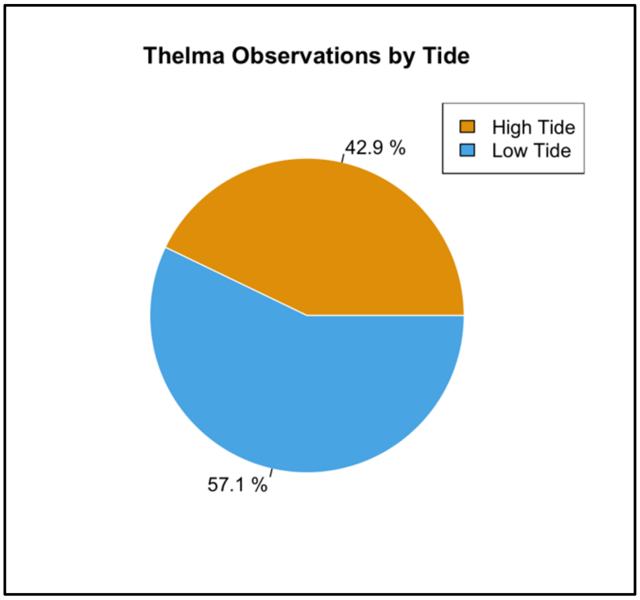

Figure 8: *Thelma sightings by tide.* A pie chart shows slightly more sightings occurred during low tide (57.1%; blue) than high tide (42.9%; orange).

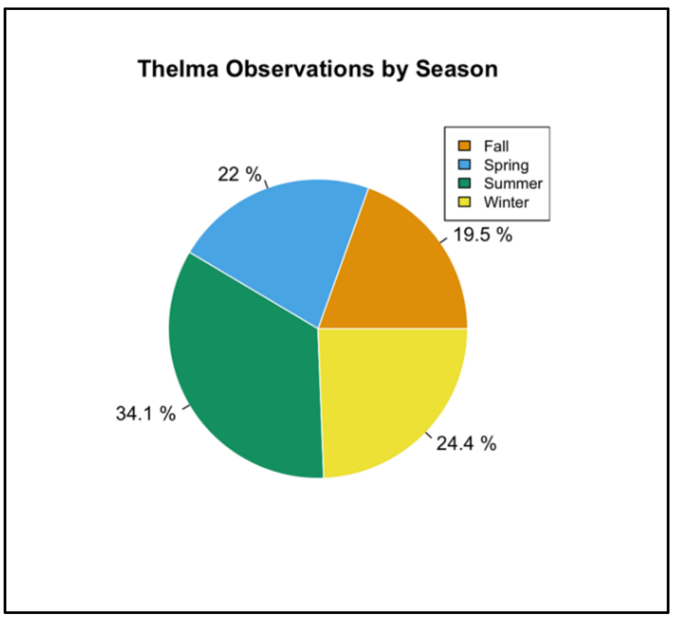

Figure 9: *Thelma sightings by season.* Most sightings occurred during summer (34.1%; green), followed by winter (24.4%; yellow), spring (22%; blue), and fall (19.5%; orange).

Temporal trends in Thelma's sightings fluctuated across years and seasons between 2008 and 2019 (Figure 10). Unlike the broader population, there was no clear pattern linking her abundance to specific years or seasons. Her presence appeared more variable over time, without a consistent increase, decline, or seasonal preference.

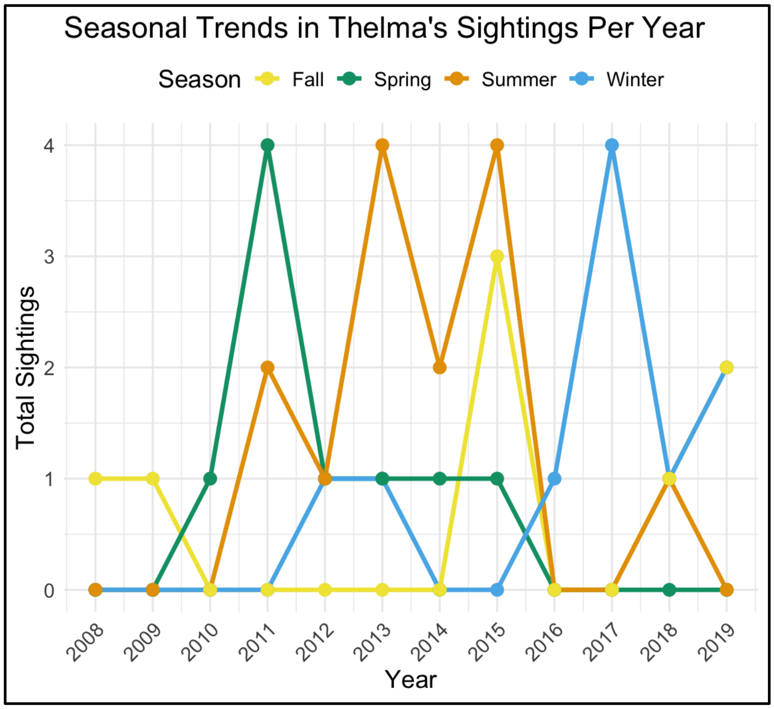

Figure 10: *Seasonal trends in Thelma's sightings from 2008 to 2019.* Sightings varied across seasons, fall (yellow), spring (green), summer (orange), winter (blue), and years, with no consistent seasonal pattern.

Finally, while there appeared to be a slight increase in Thelma's sightings at warmer temperatures, the relationship was weak and not clearly defined (Figure 11). Temperature alone did not appear to strongly influence her presence, suggesting that other factors could affect when and where she was observed.

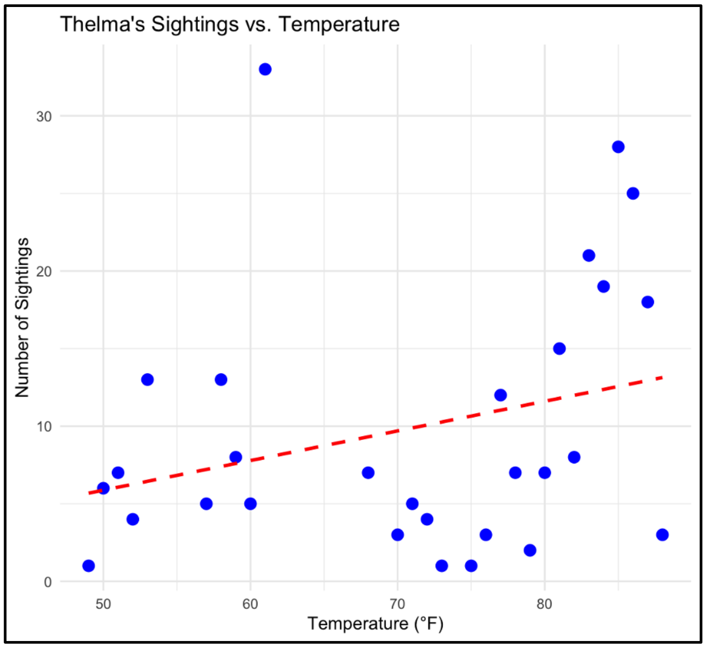

Figure 11: *Relationship between Thelma sightings and temperature (°F).* Each blue dot represents the total number of times Thelma was sighted within that temperature bin over the full duration of the study. A slight upward trend was shown by the red dashed line.

<u>Education and Outreach (RQ2b)</u>

In addition to the ecological analyses, this project included a significant outreach component developed in collaboration with Billigan Tours, a local ecotourism company operating near St. Catherine's Island. In collaboration with Captain Bill Whiteman, we designed and distributed an educational brochure and a companion story map featuring Thelma to support his business.

The brochure served as an introductory guide to common bottlenose dolphins in the region for Captain Bill's customers. It included information on their behavior, how researchers identify individuals (i.e., through dorsal fin photo-ID), where dolphins are commonly observed near St. Catherine's Island, and the greater ecological role they play in coastal ecosystems. We highlighted key conservation messages, such as the importance of responsible wildlife viewing, reducing plastic pollution, and supporting habitat protection efforts to compliment the ecotours. These materials were designed to be accessible to general audiences and incorporate and communicate local scientific data from our study.

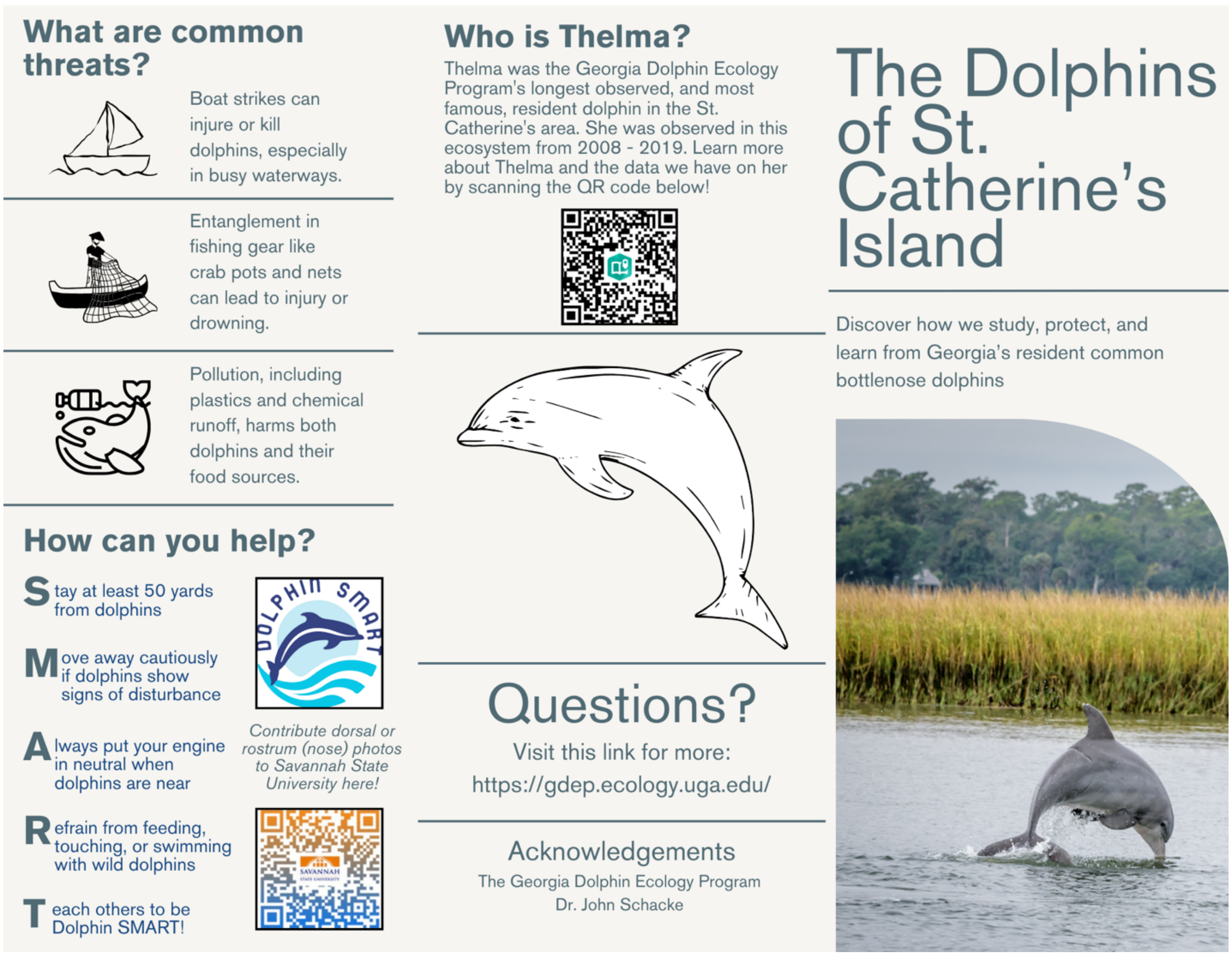

Figure 12: *Page one of the educational brochure.* This page introduces Thelma and provides information on common threats, ways the public can help protect dolphins, and how to learn more through the Georgia Dolphin Ecology Program's work.

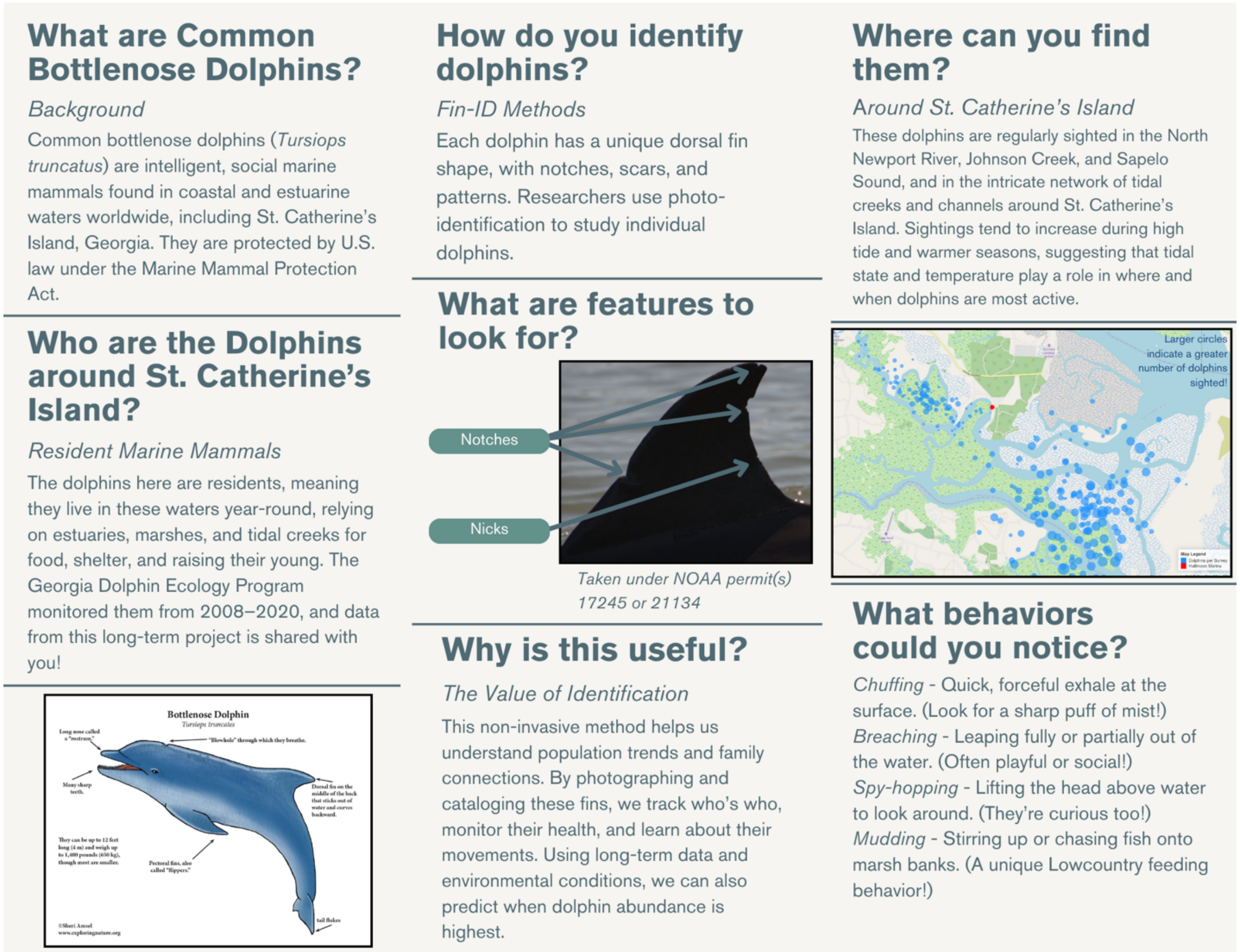

Figure 13: *Page two of the educational brochure.* This page provides background on St. Catherine's Island's resident common bottlenose dolphins, explains photo-identification methods, highlights common behaviors, and shows dolphin abundance across the island's waterways.

To complement the brochure, the Thelma story map provided a more personal narrative. By spotlighting one recognizable dolphin from the local population, we aimed to create a relatable connection between visitors and marine wildlife. Thelma's story adds a memorable face (or fin) to the science and provided us an opportunity to discuss the value of long-term monitoring using an individual's story. Her full story can be explored in an interactive format here using ArcGIS Story Map:

https://storymaps.arcgis.com/stories/4cad7b92e6944fe7985597cee96f7a57.

Discussion

This study examined how environmental variables, including tide, season, temperature, and time, influence common bottlenose dolphin abundance around St. Catherine's Island, Georgia, and how these patterns compare to the individual dolphin, Thelma. Our findings highlight both population-level trends and individual variability, with determinations for ecological understanding and public engagement.

Environmental Drivers of Dolphin Sightings (RQ1)

We hypothesized that dolphin abundance would increase during high tide, based on the assumption that rising tides provide increased access to shallow estuarine foraging areas (Fury & Harrison, 2011). However, this prediction was not clearly shown by the data. Although dolphins were observed slightly more often during high tide, the difference was minimal. This suggests that tidal state alone is not a major driver of dolphin presence in this region. This highlights the complexity of foraging behavior in local estuarine systems, where individual dolphins develop varied strategies that are not uniformly related to tide stage. Our findings are consistent with other studies in estuarine systems, where dolphin movement patterns are more closely tied to prey availability, habitat preferences, and social behaviors than to tidal cycle (Allen et al., 2001; Balmer et al., 2008).

We also hypothesized that dolphin abundance would vary by season, with higher abundance during spring and summer months. This prediction was more pronounced in our findings, with most sightings occurring during summer and spring, and far fewer recorded during fall and winter. These results are consistent with previous observations of common bottlenose dolphin populations in other coastal regions, where abundance peaks during warmer months are often linked to increased prey availability, ideal thermal conditions, and calving behavior (Speakman et al., 2010). The strong seasonal signal reinforces the idea that these ecological factors, such as food resources and reproductive activity, drive seasonal site fidelity use in resident estuarine dolphin populations.

When looking at trends over time, dolphin sightings increased in the early part of the decade, peaked around 2015-2017, and then slightly declined. This curved pattern suggests that dolphin presence in the area is influenced by a combination of ecological and anthropogenic factors over time. The initial rise in sightings from 2010 to 2017 could reflect increased habitat use, survey effort improvements, or growing familiarity with the area by a semi-resident or resident common bottlenose dolphin population- a pattern well-documented in the coastal waters of Georgia and the southeastern U.S. (Balmer et al., 2008; Zolman, 2002). However, the subsequent leveling off or decline in sightings raises important questions. If these dolphins are indeed year-round residents, as suggested by long-term photo-identification and genetic studies (Balmer et al., 2008; Rosel et al., 2009), it is possible they remain in the area during winter months but are less visible or less active in the surveyed zones. Alternatively, this decline could reflect environmental or anthropogenic pressures affecting population size or movement patterns, such as exposure to PCBs and other industrial contaminants (Balmer et al., 2008; Barratclough, 2019). Given the overlapping ranges between dolphins in Sapelo Sound and those around St. Catherine’s Island, it is possible that individuals in this population are similarly exposed to stressors that reduce calf survival or influence spatial behavior.

Several explanations could account for reduced abundance despite continued presence. Common bottlenose dolphins may shift their activity to deeper channels, offshore waters, or more sheltered estuarine zones during colder months, which can reduce their detectability during standard boat- or shore-based surveys (Speakman et al., 2010; Tyson et al., 2011). These habitat shifts could be driven by changes in prey distribution, thermal comfort, or the need to avoid areas of increased exposure or disturbance. In such environments, dolphins may spend more time submerged or in smaller, more dispersed groups, further reducing the likelihood of detection without necessarily reflecting a decrease in abundance. Seasonal changes in behavior, such as reduced surfacing frequency, smaller group sizes, or altered movement patterns, can also affect detection probability (Gubbins, 2002). These subtler behaviors make them less prominent during surveys. In addition, group composition can vary seasonally, with mothers and calves or older individuals using different habitats or exhibiting different activity levels than other demographic groups. Such behavioral flexibility has been observed in other coastal populations and highlights the importance of interpreting sighting rates not only as a function of presence, but also of behavioral state and detectability (Hartel et al., 2015).

Alternatively, subtle shifts in local prey dynamics, like the seasonal movement of fish or shrimp species, might lead dolphins to adjust their foraging locations or times of activity without completely leaving the area. For example, if prey availability decreases in shallow inshore waters during colder months, dolphins may temporarily relocate to deeper foraging grounds where they are less likely to be detected during standard visual surveys (Lopes, 2017; SeaWorld 2025). Additionally, seasonal changes in water temperature can affect both dolphin comfort and prey behavior, prompting short-term movements that are not captured by broad survey routes. In addition, human disturbances, particularly boat traffic, fishing activity, and underwater noise, can influence dolphin habitat use and movement patterns. Dolphins may temporarily avoid high-traffic areas or shift to quieter regions, especially during tourist-heavy months or in response to increased vessel noise (Pirotta et al., 2015; Wells et al., 2009). These behaviorally driven redistributions might not completely explain their absence but can still significantly change when and where dolphins are observed.

These possibilities are consistent with the observed patterns in our data, which showed that both season and year appear to influence dolphin abundance trends, highlighting the combined influence of short-term behavioral shifts and long-term ecological patterns. Similar findings have been reported in other estuarine systems, where both seasonal cues and broader habitat changes affect bottlenose dolphin habitat use over time (Gubbins, 2002; Hartel et al., 2015; Speakman et al., 2010). As such, it is important to account for detection biases and seasonal behavioral changes when interpreting survey-based abundance trends. Incorporating additional methods, like passive acoustic monitoring, photo-ID resighting histories, or predictive habitat modeling, could help determine whether reduced sighting frequencies reflect true seasonal absence or simply shifts in spatial use and visibility.

Finally, we hypothesized that dolphin abundance would increase with warmer temperatures, reflecting thermal preferences of dolphins or their prey. This prediction was supported by our observed patterns, which showed increased dolphin abundance during warmer conditions. Warmer temperatures were associated with more sightings per survey, likely reflecting seasonal movements tied to prey distribution, reproductive behavior, or general habitat preference during warmer months. This pattern is supported by dietary studies showing that common bottlenose dolphins in the southeastern U.S. feed primarily on estuarine and nearshore fish species, such as Atlantic croaker (*Micropogonias undulatus*), spot (*Leiostomus xanthurus*), pinfish (*Lagodon rhomboides*), and menhaden (*Brevoortia spp*.), which are more abundant and active in warmer months (Allen et al., 2004; Barros & Odell, 1990; Gannon & Waples, 2004). These seasonal prey dynamics likely enhance foraging opportunities in spring and summer, aligning with the observed increase in dolphin sightings during these periods.

This finding also complements the observed seasonal trends, reinforcing the idea that temperature is a key environmental factor determining dolphin abundance around St. Catherine's Island. The positive correlation between dolphin sightings and warmer temperatures likely reflects a combination of prey-driven foraging behavior, thermoregulation, and seasonal shifts in habitat use. As temperature rises, prey fish become more active and abundant in estuarine waters, while the conditions themselves may become more energetically favorable for dolphins, reducing the metabolic costs of thermoregulation (Barros & Odell, 1990; Gannon & Waples, 2004). Importantly, this temperature-dependent pattern has greater implications in the context of climate variability and rising sea surface temperatures. As global ocean temperatures continue to increase, seasonal thresholds that currently drive dolphin movements can shift, potentially altering the timing, duration, or intensity of coastal residency. For example, warmer spring temperatures could cause dolphins to arrive earlier or remain longer in estuarine habitats, while extreme heat or climate-related changes in prey availability could lead to redistribution or stress-related impacts (Albouy et al., 2020; La Manna et al., 2023).

These climate-linked shifts are not hypothetical; they have been documented in other marine predator species, and emerging evidence suggests that marine mammals are increasingly vulnerable to mismatches between prey availability and habitat conditions (Hazen et al., 2013).

For management and conservation planning, this highlights the importance of flexible, adaptive strategies that consider how environmental baselines may change. Continued monitoring of local temperature trends, combined with long-term dolphin sighting data, will be essential for predicting how this population could respond to future environmental change and ensuring their continued use of coastal habitats like those surrounding St. Catherine's Island.

Individual Variation of Thelma (RQ2)

We hypothesized that Thelma's sighting patterns would align with the broader population trends, expecting her to be observed more frequently during high tide and in warmer temperatures. However, this hypothesis was not supported. Our findings showed no clear relationships between Thelma's sightings and any environmental variable tested. While her sightings were most common in summer and at low tide, these patterns were inconsistent and ambiguous. Unlike the broader population, Thelma did not show predictable responses to the environmental drivers that were otherwise strong predictors of overall sighting rates.

There are several potential explanations for Thelma's inconsistent sightings. She might have ranged beyond the survey area or use specific microhabitats that are not fully captured in our study design. Alternatively, Thelma could have experienced health, social, or reproductive changes over time that influenced her detectability. For example, reproductive cycles can influence movement patterns, group association, and visibility. These findings highlight the value of long-term monitoring and individual-based studies, which can reveal complexities masked by population-level data.

Community Engagement and Outreach

Our partnership with Billigan Tours emerged in response to a growing community interest in sustainable marine tourism and the need for accessible, locally grounded conservation education. While Billigan Tours already introduces visitors to the unique marine life around St. Catherine's Island, our collaboration builds on this experience by offering materials that enhance understanding and encourage more mindful interactions with wildlife. The brochure provides foundational knowledge on common bottlenose dolphins, while the story map tells the story of Thelma, a resident dolphin whose legacy connects visitors to the importance of long-term monitoring and protection.

Outreach efforts, like the one in this study, provide engaging and reliable information for the general public focused on promoting ocean literacy (Worm et al., 2021). By presenting marine science in a locally relevant and emotionally resonant format, we make scientific knowledge more inclusive and approachable. This is especially important in informal learning settings like ecotour boats, where tour guides serve as key communicators of conservation values. Providing them with reliable, compelling resources not only improves the visitor experience but also promotes respectful wildlife viewing practices. Yet, as Hooper et al. (2021) found, even when captains are aware of marine mammal guidelines, compliance is uneven, and passengers often lack the knowledge to recognize violations. Educational materials can help fill this gap and create a deeper understanding of both individual responsibility and the larger ecological consequences of human disturbance.

Importantly, storytelling plays a powerful role in shaping ecotourism behavior. Visitors are more likely to take on pro-environmental attitudes when they feel emotionally connected to the species or ecosystems they encounter (Rafiq et al., 2023; Worm et al., 2021). By spotlighting

Thelma's life and her calves, we invite visitors to see dolphins as individuals with histories, social bonds, and vulnerability. Stories like Thelma's can help the general public care more by making conservation feel real and personal. Research shows that even individuals with lower baseline concern for the environment can be influenced toward more responsible behavior if they are provided with emotionally resonant messaging and knowledge-based outreach (Rafiq et al., 2023).

This outreach approach also reflects a growing shift toward inclusive and culturally responsive models of ocean literacy. Traditional marine education has often privileged formal science and excluded the diverse ways people understand and relate to the ocean (Worm et al., 2021). To build a truly sustainable relationship with marine environments, outreach must embrace experiential, place-based learning and support connections that are emotional, ethical, and local. This kind of work goes beyond simply raising awareness- it helps build a sense of ocean citizenship and shared responsibility for marine life (Worm et al., 2021).

Ultimately, our outreach materials support compliance, enhance visitor experience, and create a conservation ethic fixed in empathy and knowledge. By combining science, storytelling, and local relevance, we connect people to the ocean in meaningful ways, which is an essential step in building long-term stewardship. This collaboration with Billigan Tours is more than an educational add-on; it is a model for how researchers can actively support community-based conservation, strengthen science communication, and expand the societal relevance of their work.

Limitations

While this study provides an understanding of the environmental influences on dolphin abundance around St. Catherine's Island, several limitations should be acknowledged. First, dolphin presence was gathered from visual surveys, which are subject to detection biases influenced by weather, water condition, who was doing the observing, and dolphin surfacing behavior. Second, tidal conditions were only represented as high or low tide, which could oversimplify the influence of finer-scale tidal movements and current dynamics. Third, the study's range might not fully capture the movement of individuals like Thelma because they could travel outside of the survey area into places we did not monitor, like offshore waters or smaller estuarine zones. Fourth, while dolphin sightings were standardized by transect length to account for effort, detection probability still varies by season, group composition, and activity state. Lastly, while our long-term data set covers several years, sampling effort varied by year and season, potentially affecting sighting rates.

Conclusion

This research focuses on how environmental variables like tidal state, season, and temperature influence common bottlenose dolphin abundance around St. Catherine's Island, while also emphasizing the value of individual-based monitoring. By standardizing dolphin sightings per linear kilometer of transect, we ensured that our analyses account for variable survey effort, allowing for valid comparisons over time. These findings highlight the need for region-specific, long-term monitoring in order to understand how dolphins respond to shifting environmental conditions. Additionally, our outreach efforts demonstrate the value of integrating science with public education to connect communities with local marine life. By combining ecological research with education, we can better support both conservation goals and community engagement in coastal Georgia.

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